Report on

"Energy and Environment for Inputs into the National Conservation Strategy"

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1. Environmental Concerns and Sustainable Development

Economic theory and development strategies have generally concentrated on approaches and methodologies for increasing the growth of a country's output of goods and services as conventionally computed in national income accounts. Theories that have received widespread attention in existing literature and on the part of development organizations and governments have ranged from those of Rostow which define the conditions for attaining what was termed as the "take-off stage" to those of Schumpeter which emphasize the importance of harnessing a society's entrepreneural talent in the pursuit of economic growth. Development economics as a discipline flourished right through the 1950s and 1960s, but interest in this field has declined over the past 15 years. This is partly because of a growing insularity among the major centres of learning for development economics in the industrial nations, and also largely because of the turmoil that followed the first oil price shock of 1973-74 which created conditions that had not been faced earlier by the developing countries and their governments.

Attention to resource economics and the integration of environmental concerns while fashioning economic development strategies have received scant, if any, attention from economists in the past. Yet, the foundations of resource economics were laid over 50 years ago by Harold Hotelling. Sadly, the significance of Hotelling's work was not grasped by economists during the intervening decades and it was really the work of bodies like the Club of Rome and the scare about depletion of the world's oil resources coming to the fore in the 1970s, which led to a rekindling of interest in this area of economics. The Club of Rome raised questions largely about the finite nature of the world's raw natural and energy resources. These were easily demolished by economic thinkers, because the theories and the calculations on which these questions were based were severely flawed to the extent that they did not take into account the role of prices as an equilibrating mechanism in an economic system and substitution that took place between resources of different forms with *innovation and development of new technologies*. But, while the basis of studies such as those of the Club of Rome may have had serious shortcomings, the questions that they raised have come to visit us again almost two decades later. The major reason for the sharpening of these concerns lies in the reality that limits to growth have perhaps been reached in several ways through degradation of our natural environment. It is the extent of this degradation which is now likely to impose limits to growth if it is based on previous patterns of development.

The economic scene in India today is full of depressing examples of over-use and, in some cases, gross abuse of our endowment of natural resources. Some of these have been written about from time to time, but except for frequent seminars and discussions the planning process has not really come to grips with mechanisms by which the high social costs associated with depletion is taken into account. Consequently, the growth of the Indian economy during the forty odd years since Independence has taken place at great cost in terms of loss of the wealth that nature had bestowed on us in the form of fertile soils, forest cover, mineral resources and clean air and water. Conceivably, the steady rate of economic growth in some recent periods could perhaps even be negative if one accounts for the full value of the erosion of our natural resource wealth over time. The Government appeared to have been seized of this problem some years ago and very useful attempts were made to even inform Members of Parliament of the consequences of our present system of resource use and abuse. But, alas, these appear to have been given up despite the serious trends in environmental damage continuing to plague various parts of the country.

Nowhere is the devastation of natural resources more in evidence than in the Himalayan region. For instance, it is estimated that the rate of erosion in the rivers of this region is currently over 1 mm per year, which represents a fivefold increase over the situation at the turn of the century. As a result, the rivers are carrying sediments at the rate of 16.5 ha.m. per 100 km^2. of catchment area annually. Altogether, it is estimated that the erosion of soil in the Ganga basin alone is of the order of 6 billion tonnes per annum, and perhaps the total for all the rivers of the country may be around 15 billion tonnes per annum. If a market value were to be assigned to this quantity, we are possibly losing top soil worth around Rs 10,000 crores to the sea annually.

The major reason for this heavy rate of erosion is the widespread deforestation that has taken place in the Himalaya mountains. The National Forest Policy of 1952 set a target for afforestation to cover one-third of the land area of the country, with 60% of the hilly tracts and 20% of the plains under healthy forest cover. As against this target satellite imagery reveals that the area under good forests is currently only around 11%, and in hill areas in particular only one-third of the total surface is under forests as against 60% laid down in the National Forest Policy. If one views these figures against increases in the population of people and livestock, then the process of deforestation appears even more serious, with the per capita productive area under forests down to 0.05 hectare against 0.2 hectare in 1951. The growing demand for fuelwood and the effects of increased cattle and goat grazing can only lead to greater deforestation, not to mention the demands for timber imposed by the paper and pulp, construction and furniture industries.

Foresters are now aware of this problem, but point to the encroachment of people and grazing animals on forest areas. Goats, in particular, are regarded as a menace to the planting of trees, since they are known to devour a large variety of saplings before they can grow. Foresters see no sense in a forest policy devoid of a firm grazing and livestock policy. Others criticize the emphasis of forest departments on planting tree species which do not produce fodder. As a result of this and fodder lands not being protected, animals graze in forest areas leading to widespread damage. The traditional breakdown of societal involvement in the management of common property resources in India has been largely responsible for the encroachment on and over-exploitation of forest lands in the country. Forestry, like agriculture, requires to be moved closer to the needs of the people, by their fullest involvement in tree plantation and protection programmes. There must also be major emphasis on education and extension support in these activities. As yet, however, our plans and programmes do not show evidence of a balanced and stable approach that would ultimately ensure growth of forest wealth in the teeth of growing pressures from man and animal.

Nowhere is the concern for harmful environmental effects more pronounced than in the case of production, conversion, distribution and consumption of commercial forms of energy. Quite apart from the fact that we have burnt away most of our coking coal resources and have been flaring substantial quantities of our natural gas resources, particularly in the offshore areas, it is really in respect of the impacts of the energy cycle on air, water and soil quality that new directions and definitions are essential. The use of different forms of energy has varying impacts on the environment. Some of the environmental characteristics and the consequent ranking of energy forms in this context is shown in Table 1.1, and the manner in which the energy cycle affects the environment is shown in Figure 1.

Table 1.1: Environmental Ranking of Energy Sources

Ranking	Energy Sources	Environmental Concerns
1-4	RELATIVELY FREE OF ENVIRONMENTAL PROBLEMS	
1.	Conservation and improved efficiency of energy use	Least Impact; the most cost-effective investments, particularly in industrialized countries, the world's major consumers.
		RENEWABLE
2.	Solar	Already used for domestic hot water and solar cooking, but much unrealized potential: little impact, decentralized source.
3.	Photovoltaics	Little impact: growing source, competitiveness improving fast.
4.	Wind and Wave (including tidal)	Little impact: growing, decentralized source.
5-7	SOME PROBLEMS, BUT LARGELY PREVENTABLE OR MITIGABLE	
5.	Geothermal	Disposal of condensable where toxic (e.g., reinjection). May not always be fully renewable.
6.a.	Biomass: Fuelwood	Farm, village and peri-urban fuelwood lots; watershed management combined with fuelwood production. Precautions regarding grazing, deforestation and eucalyptus; charcoal, CO_2 sink forests.
6.b.	Biomass:	Other biogas and liquid fuels, alcohols (e.g. sugar, manihot) = annuals vs. perennials (i.e. oil tree plantations, e.g., oil palm, cepaifera, plus soya, jojoba, guayule); fast growing fuelwood (e.g. poplar, leucaena, calliandra); (erosion, topsoil, effluent concerns). Such energy is oligotrphic hence more easily sustainable than alternative eutrophic products (e.g. beef) from the same land. (The low cost C, H & O tradeoff with costlier Ca, Mg, P, K & N).

Contd/-...........

Table 1........Contd/-

Ranking	Energy Sources	Environmental Concerns
7.	Hydropower	Major problems, but largely preventable or mitigable, with more effort than at present (e.g. watershed management, diseases, resettlement); minihydro less problematic.
8-10	MAJOR RISKS; PREVENTION OR MITIGATION DIFFICULT AND SOMETIMES IMPOSSIBLE	
		NON-RENEWABLE
8.	Oil & Natural Gas	Atmospheric carbon dioxide increase, but sources depleting; better for special uses (e.g. chemical feedstock) rather than for energy. Gas emits less CO2 and often contains less sulfur.
9.	Coal	Mining, restoration, pneumoconiosis, watershed and acid pollution. Acid rain; preventable with major investments; Increased carbon dioxide not preventable but risky in view of magnitude of reserves and possibility of overshoot; better used for chemical feedstocks.
10.	Nuclear	Economically unattractive and declining at least in the USA; environmentally highly risky (e.g. waste storage, decommissioning, safety, link to nuclear weaponry). But no CO2, no acid emissions, and could become partly renewable breeder reactor; UN Brundtland Commission negative. Replacing coal implies completing a new nuclear station every 3 or 4 days for decades.

Note: This is an informal, tentative ranking only, based mainly on environmental considerations. Addition of other considerations will alter the ranking. The broader and more decentralized the mix of energy sources, the more reliable, sustainable, and robust the total system will become.

Source: World Bank

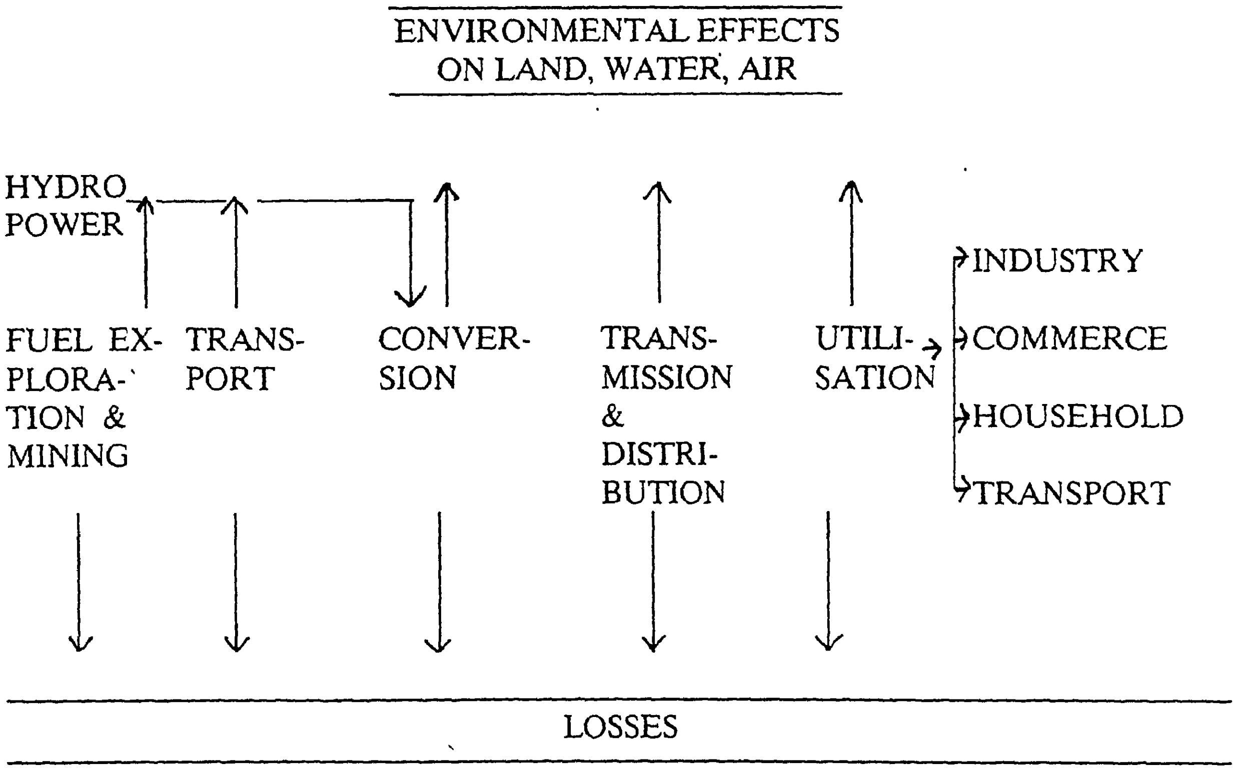
ENVIRONMENTAL EFFECTS ON LAND, WATER, AIR
HYDRO POWER
FUEL EXPLORATION & MINING
TRANSPORT
CONVERSION
TRANSMISSION & DISTRIBUTION
UTILISATION
INDUSTRY
COMMERCE
HOUSEHOLD
TRANSPORT
LOSSES

FIGURE - 1

2. Energy Environment Interface

The environmental impacts associated with various forms of energy are very different and may influence the mix of energy sources to reflect national priorities on conservation of natural resources. Hence it is necessary to have an overview of environmental impacts of different forms of energy, whose magnitude depends on the technologies of energy production and use as well as on various pollution control measures. In this context, the environmental impacts associated with different forms of energy production - coal, oil, gas, power generated by hydro, thermal (coal), nuclear and biomass - and different end uses e.g. households using biomass fuels and road transport vehicles using petroleum products, are all important. We summarize a description of these impacts here along with a description of the present mitigation measures to achieve different standards.

2.1 Coal Mining

Coal production in India increased rapidly from a level of about 73 MT in 1972-73 to 194.6 MT in 1988-89. The share of open-cast mines in the total production was about 60% in 1988-89. The demand for coal in 2004-5 is estimated at 520 MT. Almost 48% of this demand will be realized by commissioning new projects primarily from open-cast mines. This ambitious programme for coal production will demand acquisition of large surface lands with varying degrees of impact on the environment and ecology.

Environmental Concerns: Coal mining, preparation and transportation are three distinct and sequential operations which

The land requirements for mining activity are generally very large; the mines are generally located in sparsely populated forest areas and/or agricultural land and in some cases in thickly populated areas as in Raniganj coalfield in West Bengal and Jharia coalfield in Bihar. The changes in the existing land use pattern result in problems related to rehabilitation, and/or ecological imbalance.

Uncontrolled fires resulting from spontaneous combustion in abandoned mines, coal piles and overburden dumps (containing carbonaceous materials) are a major source of air pollution and can smoulder for years, producing noxious gases. Surface mining emissions come primarily from diesel equipment and blasting operations which produce fine particulates, nitrogen oxides, sulphur oxides and hydrocarbons.

Adverse environmental impacts result from discharge of mine water into streams and water bodies; leaching and erosion of coal dumps and waste dumps; discharge from cleaning plants; slurry dewatering and modification of aquifers during mining. Water quality can be affected though the interconnection of vertically adjacent aquifers and by seepage of contaminants from waste disposal piles. Ground water impacts from mining in or near aquifers are site specific. Diversion of local surface water drainage may affect both regional hydrology and erosion patterns. Where a mine is located below the water table, seepage of water into the mine can lower the water table and dry up wells in the area.

Because of variations in seam thickness, mining technique and levels of production, land use impacts vary from mine to mine, but all remove land from its current use. Overburden heaps from poorly controlled dumps are vulnerable to erosion and can lead to landslides.

Subsidence from underground mines can have severe impacts on roads, water and gas lines, buildings and local hydrology. The extent, severity and timing of subsidence depend on the thickness, depth of the coal seam, the overlying rock characteristics and mining method.

There are major occupational hazards associated with mining. The workers inhale large quantities of dust, fumes and gases which can cause respiratory diseases like pnumonconiosis, bronchitis, severe dyspnea and airways obstruction. Noise is another proven hazard to the workers in a mechanized mine with three possible effects - temporary or permanent loss of hearing sensibility, physical and psychological disorders, and interference with speech communication and disruption of job performance.

Mitigation Measures: Mitigation measures for management of air and water quality are being adopted on a large scale in mining areas. However, the major environmental concerns in coal mining are related to the changes in land use pattern and their consequences on the ecosystem, including people. Rehabilitation of the affected population has become a major issue in expanding the mining operations and in acquiring land for new mines. The Ministry of Environment and Forests under the Government of India has stipulated that in every coal project, a scheme for restoration of mined land to conditions permitting its pre-mining use is to be included in the overall environmental management plan (EMP). Also, the state forest departments insist on afforestation of degraded lands to compensate for the forests destroyed due to mining operations.

Environmental Management Cost: In the integrated environmental management plan prepared for different coalfields, cost of land reclamation, rehabilitation, and environmental control measures are generally estimated.

Based on various project feasibility studies, the long run average economic cost of production over a planning period up to 1999-2000 is Rs 198/- per tonne for non-coking inferior coal to Rs 374/- for prime coking coal at 1984-85 prices. In this, the cost of environmental management varies from Rs 6/- per tonne for open-cast to Rs 1.5/- for underground mining. These costs cover the cost of rehabilitation, land reclamation and afforestation. Table 2.1 gives a breakdown of costs of all environmental control measures in case of Bina open-cast mine.

Table 2.1: Cost of Environmental Control Measures

Control Measures	Bina Open-cast Mine	
	Capital Expenditure (Rs/lakhs)	Cost per Tonne (Rs)
A. Expenditure which would become part of mining operation		
i) Technical reclamation	434	4.32
ii) Community development	13	0.10
iii) Rehabilitation	5	0.07
iv) Compensation for land	40	0.31
Sub Total	492	4.8
B. Expenditure directly attributed to pollution control		
i) Air pollution control	122	0.84
ii) Water pollution control	42	0.26
iii) Biological reclamation	-	0.20
iv) R & D including monitoring	-	-
Sub Total	164	1.3
Grand Total	656	6.1

A large part of the existing and future coal mining areas falls in environmentally sensitive watershed areas requiring essential vegetation protection to maintain/restore equilibrium of the basinal land water systems. Hence it will be necessary to examine the feasibility of mining in such environmentally sensitive tracts where mitigation measures may not protect the ecological balance. Some of the environmentally sensitive coalfields would be Ib valley, Talcher and Godavari where large tracts of forest land and water bodies are involved. The environmental management plan should ensure the involvement of the local population in various aspects of reclamation and land use both during and after mining operations. These activities will require manpower with suitable technical background.

2.2 Power Generation

The power supply situation in India is characterized by some serious shortages. It is proposed to increase the installed capacity of 64,424 MW in March, 1989 to 1,74,649 MW by the end of 1999-00. The mix of thermal-hydro-nuclear is expected to change from 67:30:3 at the end of the Seventh Plan (1985) to 60:34:6 by 2000 AD. The environmental impacts associated with different methods of power generation are quite varied.

2.2.1 Thermal

The bulk of the electricity demand in the country will continue to be met by thermal power. The installed capacity due to thermal power plants is expected to increase from 42,463 MW in 1989-90 to 1,04,789 in 1999-00.

Environmental Concerns: In coal-fired power production plants the activities with significant environmental impacts include coal handling and storage, coal combustion, steam generation, condenser cooling, electric generation, flue-gas cleaning, solid-waste handling and disposal, and wastewater treatment.

A large 2000 MW thermal power plant uses 1400 ha for the power plant, colony and ash dumping i.e. 0.7 ha/MW whereas smaller plants of capacities of 800 MW (4 x 200 MW) and 440 MW (4 x 110 MW) require 650 and 440 ha i.e. 0.8 and 0.9 ha/MW respectively. This poses problems regarding rehabilitation of the displaced people and related impacts on the ecosystem due to changes in the land use pattern.

The major air pollutants in the air are emissions of SO_2, NO_x, CO_2 and TSP. In recent years, concern has grown over the possibility of climatic changes brought about by increasing carbon dioxide levels in the atmosphere because of its absorption of infra-red radiation from the earth. High levels of carbon dioxide in the earth's atmosphere may therefore, produce a "greenhouse effect", thus increasing the global temperature.

The solid-waste products of coal combustion - flyash and bottom ash (and scrubber sludge if FGD (fluidized gas desulpherization) process is carried out) - pose major waste disposal problems mainly because of the large quantities produced as a result of the high ash content of Indian coals. Ash disposal involves potential problems of pollution of surface and subsurface water.

Wastewater discharges can cause adverse effects on aquatic ecosystems. Discharges from the once through cooling systems release waste heat into water systems resulting in an increase of water temperature by 10^{o} C.

Mitigation Measures: The Central Pollution Control Board has set standards for particulate emissions from boilers, pollutants in condenser cooling waters, boiler blowdown, cooling tower blowdown and ash pond effluent.

The stringent limits on emissions make the use of highly efficient particulate collectors such as electrostatic precipitator (ESP) necessary. Sulphur dioxide emissions reach high levels only due to clustering of thermal power plants. At present the Central Pollution Control Board recommends stack heights for different boiler sizes to keep the ground level concentration of SO_2 within limits. However, the Central

Pollution Control Board stipulates that there should be a space provision in the layout of power plants of capacities 500 MW and above, so that FGD systems could be installed in future, if necessary. The cost of an FGD system has been a major consideration in the evaluation of environmental impact vis-a-vis socio-economic benefits of thermal power stations. As of March 1989, there was only one FGD installation in India for a power plant (at the Tata Electric Company's plant in Trombay). In case of NO_x, the emissions do not result in the ambient level above the recommended air quality standard, and hence, the Central Pollution Control Board has not recommended control technologies, though these exist.

Thus, control technologies exist for limiting the emissions of SO_2, NO_x and TSP and are being increasingly adopted. However, the emission of CO_2 alone has the potential to justify action to restrict or even, ultimately, completely ban coal combustion for power generation since technological measures for removing CO_2 from the atmosphere are prohibitively expensive and also result in producing more solid or liquid waste.

Ponding and landfill are the two major options for disposal of bottom ash, flyash and FGD scrubber sludge. But both these options require large land areas, which will have to be reclaimed later by afforestation etc.

Cost of Environmental Management: In India, a typical spray dryer system on a boiler utilizing low sulphur coal would increase the cost of power generation by approximately Rs 0.154/kWh to 0.300/kWh. For new plants, ash management would increase the cost by approximately Rs 0.18/kWh. For super thermal plants the cost of environmental management is estimated to be 10-12% of the total project cost.

2.2.2 Hydro-Power

Large scale hydro-electric systems were justified in the past due to their longer operational lifespan, lower maintenance costs and multiple benefits (flood control, irrigation, recreational facilities etc.) in spite of higher initial costs and longer gestation periods. They were also preferred for meeting the peak load demand. The installed capacity of hydro-power in the country is expected to increase from 17,500 MW in 1989 to 67,500 MW by 2000 AD.

Environmental Concerns: Environmental concerns of hydro-projects are site specific, but can be broadly classified as physicochemical, biological and social. The impacts on reservoir and surroundings, and on downstream effects are quite different. The physicochemical effects on reservoir and surrounding areas are earthquakes, sedimentation etc. while the downstream effects are flooding, water logging, salinity, receding of deltas etc. The biological impacts are associated with drop in fish harvests, a number of water-borne diseases and destruction of flora and fauna. The displacement of a large number of families creates major social impacts in the region.

The other major impacts are loss of forest cover and vegetation, resulting in soil erosion. Deforestation also contributes to the greenhouse gases.

Mitigation Measures: There are methods based on hydrologic and engineering data for ensuring safety in reservoir construction. However, in the past, there have been accidents resulting in loss of life and property. The problems associated with the sustainability of ecosystems are not fully understood and probably cannot be fully accounted for. The present mitigation measures are restricted to rehabilitation, afforestation and catchment area development.

Cost of Environmental Management: The capital costs and the O&M costs of environmental management in hydro-projects are estimated to be about 16% and 1% of the total project cost respectively.

The larger lifespan of hydro-power projects is now being doubted due to heavy siltation of reservoirs. The problem of rehabilitation and limited understanding of ecological imbalances calls for a more cautious approach towards the development of large hydro-power projects.

2.2.3 Nuclear Power

The installed capacity of nuclear power is expected to rise from 1,230 MW in 1988-89 to 2,975 MW by the year 1995.

Environmental Concerns: The risks due to nuclear power plants are directly related to the radiological impact which is aimed at being kept as low as reasonably achievable (ALARA) both during normal operation as well as accident conditions in all nuclear programmes. The radiological concerns of nuclear power plants are - air-borne effluents (fissionable gases, Tritium, Argon-41, Carbon-14, Iodine-131 and particulates) and liquid effluents

(Tritium and other radionuclides). Nuclear reactors also produce large amount of solid wastes. The most pressing environmental concern is the possibility of accidental releases of radionuclides. The non-radiological concerns are land requirements (1000-5000 ha for 2000 MW), thermal discharges etc. Unlike other power generation technologies, the risks associated with nuclear power were so prominent that since its inception, safety has been a major factor in the planning of nuclear power plants.

Mitigation Measures: All nuclear installations are designed with built-in safety features that (1) prevent accidents, (2) limit the magnitude of an accident should one occur, and (3) limit the consequences of an accident should (1) and (2) fail concurrently. Elaborate measures have been undertaken to achieve safety in siting, design and operation of nuclear power plants. The standards for radioactive releases to the environment are based on the recommendation of the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA).

Rigorous environmental surveillance is maintained to monitor levels of radioactivity. In spite of these measures, the intergenerational impacts of an accident, the long gestation periods and poor performance have raised serious doubts about the desirability of expanding nuclear power.

The major environmental concerns of different large scale power generation methods are very different - in the case of thermal power, disposal of flyash and emissions of CO_2 are the major environmental problems; in the case of nuclear power, these are related to the long term effects of radiation particularly in the event of an accident; whereas in the case of hydro-power the impacts on ecological balance are of a critical nature. Common to most large-scale projects is the question of rehabilitation of displaced people for which a satisfactory solution is yet to be found. In Table 2.2, effluents in air (particulates, SO(X), NO(X), CO, HC, CO_2 etc.) from large scale power generation by different methods are compared.

Table 2.2: Effluents from Power Stations
(In Tonnes/GW(e)-y)

Effluent	Coal	Gas	Oil	Hydro
Particulates	3,000	510	1,200	
SO(x)	55,000	20	37,000	
NO(x)	27,000	20,000	24,800	
CO	2,000	-	710	
HC	400	34	470	
Aldehydes	-	-	240	
Other organic compounds	-	238	-	
CO2	766.3x104	402.1x104	600.6x104	134.6 x 104

Data Sources and Assumptions

1. Data on power generation - TERI Energy Data Directory and Yearbook (1987).
2. Data on submergence of land - Department of Environment.
3. Emission factors for coal and natural gas fired power plants - Integrated Energy Planning: A Manual, Vol.III - Energy Policy edited by Rene Codoni, Hi Chun Park and R.V.Ramani.
4. CO2 absorption by the forest cover - The Global Warming Seminar Summary Report, American Petroleum Institute, Washington DC, USA, 1987.
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2.3 Hydrocarbon Development

The total production of crude oil and natural gas was 30.13 MT and 8.14 billion m^3 respectively in 1985-86. The production is increasing at an average rate of 13.5% p.a. The major share of oil and gas production in India is from offshore reserves (70% oil and 60% gas). About 63% of the prognosticated reserves are offshore. As of 1988, there were 12 refineries in India, with a total annual throughput capacity of 46.7 MMT. The major portion of oil and gas exploration and development in the country is expected to be in the Bombay and Cambay basin till 2005 AD.

Environmental Concerns: Potential adverse environmental impacts from oil and gas production facilities are related to oil spills and disposal of drilling mud.

When oil is spilled onland, it spreads out, sinks and can contaminate ground water. How much of it will sink depends on the type of oil, its volume and viscosity and the type of soil. Computer models show that oil entering the water table can persist for a hundred years. The rate at which oil penetrates groundwater and its concentration is both oil and site specific depending on such factors like the rainfall in the area, the rate of evaporation of oil and its biodegradation.

When oil is spilled at sea, it undergoes both physical and chemical changes, some causing it to disappear from the sea, others causing it to persist. Ultimately it is assimilated by the marine environment but the rate at which this happens would depend on the type of oil, the prevailing wind and sea conditions and where the oil ends up.

An oil spill can cause damage to fisheries, birds and intertidal plants. Fish resources are of particular concern in the Indian situation not only because they fetch considerable foreign exchange but also because a large number of fishermen are entirely dependent on the catch for a living. An oil slick is likely to damage coastal fisheries more than deep sea fisheries. Given that artisanal fishermen fish in the nearshore areas and that they have few alternative employment opportunities, the impact on them from an oil spill should be of particular concern in studying the interface between energy and the environment. In addition to lethal effects, crude oil can affect organisms at concentrations that do not cause death but lead to chronic toxicity, interference with feeding and reproduction, abnormal growth, etc.

Of the various coastal zone ecosystems in general, those that are sheltered, with low wave energy environments, tend to be more vulnerable than those exposed, with high wave energy environments. Within the sheltered zones, the ecosystem that is particularly vulnerable to oil spills is the mangrove swamp. The ecological impacts of oil and gas development are less harmful the farther the offshore facilities are from the coast. Dilution in deep waters will reduce the impact of the oil spill. Coastal areas tend to be more productive, have more shallow water and support a complex community of fauna and flora that may be vulnerable to oil spills.

Transportation of oil or LNG in large tankers may result in accidental spillages and subsequent impacts. The environmental impacts associated with oil refining are - i) land and water requirements, ii) airborne and liquid effluents and iii) other hazards arising from the risk of fire explosion.

The refinery process produces both gaseous and liquid effluents. The major gaseous pollutants are nitrogen, hydrocarbon, ammonia and carbon monoxide while wastewater contains BOD, COD, oil, phenols, dissolved solids, dissolved sulphides, ammonia, hydrogen sulphide, hydrocarbons and cyanides.

Mitigation Measures: To calculate the potential contamination caused by the dumping of chemically treated mud one has to know the amount of consumption of chemicals per typical well, make an assumption about the time taken for the water body around the drilling site to renew itself so as to determine the accumulation of chemicals, find their concentration level and compare these with known toxicity levels and estimate the "safety factor". If water quality standards have been established these can then be used to regulate discharges. In general, oil-based muds should not be allowed to be discharged in the water.

The risks of oil spillage from blow-outs or accidental releases cannot be regulated. Hence a high level of contingency planning is required. Where offshore oil is involved, in order to draw up contingency plans, it is necessary to have an appreciation of the likely fate of potential spills. One can make predictions about the lifetime of the oil slick and the quality and nature of the residues if data on type of oil and weather parameters is available.

Given the fact that considerable exploration activity is being planned both onshore and offshore, it is necessary to develop an inventory of the natural resources that could be at risk and to establish vulnerability indices for these.

There are national emission standards for effluents in refinery wastewaters as well as for SO_2 emissions from different units in a refinery.

Costs of Environmental Management: If an accident takes place during offshore operations, the operator-company will face a number of costs to clean up, to control the well, to contain the oil, etc. These are the clean-up and the well control costs. Besides, it will face claims from third parties for the damage caused to their property or environment. There will also be the cost of the oil lost and production and profit losses from a suspension of operations.

Oil exploration and production activity has to date not been a significant contributor to the total oil that enters the marine environment. However, the duration of damage and the economic importance of offshore oil exploration and production activity implies that an accident, when it does occur, can cause considerable damage locally and involve enormous costs to the environment and industry. The possibility of such an occurrence implies, therefore, the need to understand its implications when hydrocarbon development is being planned.

2.4 Biomass

It is known today that the country's forest area is about 11%, as against the recommended 30%. The demand for firewood is expected to be about 230 million tonnes by the year 2000. The recorded production is only about 13 million tonnes. Crop residues and dungcakes are also used in large quantities for cooking and water heating.

Environmental Concerns: The excessive use of woody biomass for energy and non-energy activities has resulted in large scale deforestation which in turn has led to soil erosion, water run-off and has aggravated the problem of cooking energy supply in rural and urban areas. Deforestation also contributes to greenhouse gases. The use of dung as fuel deprives land areas of organic manure.

Mitigation Measures: On the supply side, a large number of programmes to afforest degraded land, to develop energy plantations and to encourage agroforestry are being implemented with support from the Government. However, we do not seem to have come to grips with the problem. Some of the reasons are related to promotion techniques while the others are related to competing uses of land and biomass.

On the demand side, programmes to promote biogas and improved stoves are being implemented to obtain fuel and fertilizer benefits of biodigesters and to reduce the consumption of biofuels.

Cost of Environmental Management: The present methods of incorporating the costs of loss of biomass do not reflect the extent of damage to the ecosystem and hence the cost of biomass products are generally underestimated.

2.5 Transportation

The major environmental problem associated with transportation is air pollution due to road transport in metropolitan cities.

Environmental Concerns: Major contributors to the vehicular pollution are the two-stroke engine-powered motorcycles, scooters, mopeds etc. which are becoming increasingly popular in India because of their greater fuel economy, better specific power output, lower operational and maintenance costs as also lower production costs. India is the third largest producer of motorcycles/scooters in the world and these two-wheelers account for more than 50% of the country's gasoline consumption. Their exhaust effluent contains around 2 times higher concentration of carbon-monoxide and around 7 times greater proportion of hydrocarbons, as compared to that in the exhaust of four-stroke engine-powered cars.

Another significant contributor to the vehicular pollution are the diesel-powered heavy vehicles, which are widely being used in India for public transport in the form of buses and for hauling of goods in the form of trucks. India is the second largest producer of these diesel-powered heavy vehicles in Asia.

Vehicles plying in the metropolitan cities of Delhi, Bombay and Calcutta are estimated to account for about 70% of all carbon-monoxide, 50% of all hydrocarbon, 30 to 40% of all oxides of nitrogen, 30% of all suspended particulates and 10% of all sulphur dioxide pollution in these cities. In Delhi and Bombay, vehicular exhaust accounts for more than 50% of the total pollution from all sources put together. The exhaust effluent from these vehicles contains, apart from above mentioned gaseous pollutant, huge quantities of carbon and soot particles which cause smoke pollution.

Mitigation Measures: The ISI standard of smoke density is 65 H.S.U. In general, the control techniques can be classified into two categories. They are either employed to prevent the formation of the pollutants, or once formed, to destroy them.

Formation of hydrocarbon in the case of vehicle engines is unavoidable because of the flame-quenching phenomenon. These hydrocarbons find their way to exhaust causing thereby exhaust hydrocarbon pollution. The available techniques for their control involve their destruction in the exhaust system by further oxidation. It may be unnecessary to supply additional oxygen or to alternatively use catalysts to achieve their destruction in a reasonable size converter.

Because of the inherent nature of the combustion process in the diesel engine, where unlike in the gasoline engine, the mixture is more heterogeneous, it is almost impossible to completely eliminate traces of smoke and odour from the diesel exhaust. However, diesel exhaust smoke emission can be minimized by (i) proper engine maintenance, (ii) engine derating and (iii) use of fuel additives.

Cost of Environmental Management: In spite of the availability of a number of options to reduce pollution, their adoption is still limited.

2.6 Cooking

In the domestic sector, the share of traditional fuels (fuelwood, crop residues and animal wastes) was as high as 90% in 1984-85.

The trends in the relative shares of different fuels for cooking show that in 1987-88 the traditional fuels accounted for 89% and 47.5% of the cooking energy in rural areas and urban areas, respectively. The shortage of commercial fuels (particularly of LPG and kerosene) and of firewood has become a common feature in most parts of the country. Hence, as far as cooking fuels are concerned, it can be assumed that -

1) majority of rural households and a significant number of urban households will continue to use traditional fuels.
2) the quality of traditional fuels may deteriorate further.

Environmental Concerns: For examining the environmental impacts of energy use in cooking, the use of biofuels for cooking is considered. Four broad categories of environmental impacts are associated with the combustion of biofuels for cooking, viz.

1) Ambient air quality
2) Indoor air quality
3) Global warming
4) Deforestation and consequent environmental effects.

However, we will focus on the indoor air quality as the biofuel combustion seems to affect the health of a large number of people, particularly women and children.

Of the five pollutants criteria - suspended particulates (TSP), sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO) - the combustion (large and small scale) of wood results in significant emissions of TSP, HC and CO. The wood smoke literature has focused more on particulates, carbon monoxide, benzo(a)pyrene (BaP) and formaldehyde (HCHO).

Mitigation Measures: Changing fuels, improving ventilation conditions and using biofuel stoves with flues seem to be the options to reduce exposures.

At present, as the economic status of a household improves, depending on availability, the commercial fuels are used for cooking. However, for a vast majority, unprocessed biofuels are the only cooking fuels, till cleaner fuels (perhaps processed biofuels) are available at lower costs.

Improving ventilation conditions of the kitchen, seems to be a long term option that needs to be developed under different agro-climatic and socio-cultural conditions.

The more immediate solution appears to be stoves with fuels and other measures to improve fuel efficiency e.g. (improved stoves, pressure cookers). The National Programme on Improved Chulhas can contribute to reducing exposures provided the stoves can achieve reliably high efficiency, low human exposures, and social acceptability.

In Table 2.3, for some of the enduses, we have estimated likely increases in the level of air pollutants by 2004-05 over the emissions in 1984-85. The percentage increase in emissions is computed assuming no improvements in technology, hence using current emission factors. Hence, they represent the worst case. The increase in emissions varies from 71% to 1000%. It is important to examine the choices before us to reduce the emissions so that the adverse effects on the environment are minimal.

Table 2.3: Estimates of Present and Future Annual Emissions from Various Energy Sources

('000 Tonnes)

Fuel	End Use	Year	SO2	CO	HC	NO(x)	TSP
Coal	Power Plants	1984-85	608	22	4.3	298.6	33.0
		1999-00	2386	88	17.1	1171.2	129.3
	Percent increase in emissions - 292						
Coal	Boilers	1984-85	605	-	-	148.3	24.7
		1999-00	1467	-	-	360.0	60.0
	Percentage increase in emissions - 143						
HSD	Road transport	1984-85	-	193	74.8	365.0	12.1
		1999-00	-	570	220.8	1077.5	35.8
	Percentage increase in emissions - 195						
Petrol	Cars	1984-85	-	485	73	32.3	-
		1999-00	-	1401.6	210.2	93.4	-
	Percentage increase in emissions - 188						
Petrol	Two-wheelers	1984-85	-	197.5	123.3	-	-
		1999-00	-	2126.6	1327.2	-	-
	Percentage increase in emissions - 976						
Petrol	Three-wheelers	1984-85	-	103	64.3	-	-
		1999-00	-	1148.7	717.3	-	-
	Percentage increase in emissions - 1015						
Fuel-wood	Domestic stoves	1984-85	-	2491	-	-	278.4
		2004-05	-	4401	-	-	491.9
	Percentage increase in emissions - 77						
Dung-cakes	Domestic stoves	1984-85	-	2489	-	-	393.5
		2004-05	-	4666	-	-	737.6
	Percentage increase in emissions - 88						
Crop Residues	Domestic stoves	1984-85	-	1218	-	-	135.3
		2004-05	-	2079	-	-	231.0
	Percentage increase in emissions - 71						

Assumptions

1. Estimates of the Energy Demand Screening Group (Planning Commission, 1986, Government of India are assumed).
2. Emission factors of pollutants from power plants are derived from Environmental Sources and Emissions Handbook by Marshal Sitting, 1975.
3. Emission factors for industrial boilers are from Coal Processing and Pollution Control, T.F. Edgar, 1983.
4. Emission factors for domestic stoves using different fuels are from Emissions from Burning Biofuels in Metal Cookstoves, V. Joshi, C. Venkataramana and D.R. Ahuja, Environmental Management, Vol. 13, No. 6, 1989.
5. Estimation of Total Road Transport, Freight and Passenger Movement in India for the year 2000 AD, Final Report submitted to the Department of Surface Transport, Government of India, Engineering Consultants Pvt Ltd, New Delhi.

3. Strategic Issues in Energy Development

The nexus between energy development and the environment has two components to it: on the input side, the problem is one of exhaustible fuel resources and on the output side, it is one of the limited capacity of the environment to accommodate without adverse impacts particular activities, and rates of activity.

Hence our energy choices depend not only on the form of growth and the nature of energy demand being planned, but also on the importance we give to the environment in our definition of social welfare and on the technological options we choose.

At present, the production and consumption of energy creates a number of external effects that are not captured by its pricing. The resultant price signals to producers and consumers lead to demand and supply patterns that do not reflect the costs to society of these activities. The allocation of resources that follows is not socially optimal.

In the absence of clear rules about rights and liabilities relating to environmental resources, there are no incentives to avoid pollution or overuse of resources.

Another reason for ignoring the nexus between energy development and its impact on the environment could be a very narrow view of the benefits and the costs associated with the various energy forms, resulting in an underestimation of the costs associated with conventional energy forms and an underestimation of the benefits associated with the non-conventional energy forms. The result of this has been a bias of policy in favour of the conventional energy forms.

The current energy policy in India is supply oriented. The approach to developing energy supply sources is to meet energy demand. Projections of future economic growth are closely associated with projections of increased energy demand and the need for continuous expansion of energy supplies. This continued supply expansion is proving to be increasingly difficult to achieve in terms of financial and material resources and has hazardous and uncertain consequences for environmental resources. In brief, the prospects of current energy policy to meet the high estimates of future demand extrapolated from present growth patterns are likely to be unsustainable.

The power sector accounts for nearly 75% of total energy outlays. Following the price shocks of the early 1970s, a tremendous thrust was developed towards increased exploration of domestic sources of oil and towards a substitution of oil use through the use of non-coking coal. Thus some investments were diverted to the coal industry as also to the oil sector. The investments in the oil sector increased significantly resulting in an increase in the reserves to production ratio from 17.2 in 1972-73 to 31.3 in 1980-81. However, this ratio has once again declined to 19.2 in 1987. The investments in developing new and renewable sources of energy are still insignificant.

The critical issue in the energy-environment interface in India which is of major importance to a strategy for sustainable development arises mainly from the severe fuelwood crisis. Fuelwood still meets 54% of gross rural household energy demand and 50% of urban household energy demand (In useful energy terms this share comes down to 52.3% and 24.8% respectively) [Source:

Dharmarajan, K., "Urban growth and household energy", Energy Policy Issues, Vol. 4 (1988), Tata Energy Research Institute, New Delhi]. However, this energy source has received scant attention in the past and its shortage has increased the use of animal dung and crop waste. While energy related issues shot to the forefront in the 1970s and early 1980s resulting from the increase in international oil prices, they are once again in the forefront for reasons related to the environmental impacts of energy use both at the local and the global levels. Global environmental issues include the effects of greenhouse gases, impact of ozone depletion and the acidification of the atmosphere. National environmental problems include the growing pressure on our land areas which may result in further ecological damage and impacts associated with rehabilitation of people. At present, a well developed framework to examine the energy-economy-environment linkages does not exist.

An effort is made here to examine the impact of a few strategic choices in energy on the environment. Energy choices can be divided into those relating to energy supply, energy conversion, and energy use.

3.1 Energy Supply Choices

On the supply side, choices relate to the development of commercial forms of energy, biomass forms of energy and other renewable forms of energy.

Less than 2% of total marine oil pollution is estimated to be from the crude oil production from off-shore fields. The balance is attributable to marine transportation. Thus, at least theoretically, we have a choice in deciding whether to increase the domestic oil production thereby reducing marine transportation of crude oil. Domestic crude oil also has the advantage of significantly lower sulphur content as compared to imported crude whose sulphur content has been showing an increasing trend.

The quality of coal has been declining steadily and the ash content of the coal is expected to increase to over 40% by the turn of the century. This is attributable to two factors: (i) good quality coal reserves in the country have already been exploited to a large extent and (ii) there is an increase in dependence on open cast mining technology which results in coal with higher shale/stone content. Thus, in addition to being more environmentally harmful at the mining stage, coal produced from open cast mines has more serious environmental implications at the combustion stage as well. Transportation requirements of such coal in terms of useful energy provided are also significantly higher. Also, in view of the large land requirements, we need to examine the options for substitution of coal by other fuels.

Large reserves of natural gas have been discovered in the late 1970s which took up the reserves to production ratio from 35 in 1974 to a peak of 169 in 1980. Unfortunately the markets for natural gas as well as the distribution network are yet to be developed. As a result, a significant amount of natural gas is being flared. Of the 1.83 billion m^3 of natural gas produced in 1985-86 61% was utilized, 0.8% was reinjected and the balance of a little over 38% flared. It is estimated that in terms of CO_2

emissions, oil emits 38-40% more CO_2 and coal emits 72-95% more CO_2 than natural gas. While it is expected that the use of commercial forms of energy - fossil fuels in particular - is going to increase in the years to come, there do exist significant possibilities of substitution within the fossil fuels group as such. Example of such substitution are the use of natural gas for power generation (substituting for coal), transportation (substituting for oil), industrial process heating (substituting for coal & oil), domestic energy, etc. This may have several benefits such as utilization of domestically available resources, favourable economics, more benign in its impact on the environment.

Renewable technologies on which adequate R&D has been undertaken include solar thermal (solar cookers, solar hot water systems), solar photovoltaics, wind farms (for pumping and power generation) and biogas. However, the contribution of these forms of energy is not expected to be more than 1-2% by the turn of the century.

3.2 Energy Conversion Choices

The demand structure for petroleum products in India has historically shown a bias towards the consumption of middle distillates and this trend still continues. As a result, we have an imbalance between the domestic refinery configuration and the demand pattern of petroleum products which has resulted in fairly large imports of high speed diesel and kerosene in particular. As a number of countries have set up export refineries it may well be desirable to import those petroleum products for which we have an excess demand rather than to import the crude oil and set up additional refining capacity to meet these requirements. This argument would have to be looked at in terms of capital resources required for setting up additional refining capacity and the foreign exchange implications of such a strategy in a capital-scarce, foreign-exchange-scarce economy like India.

Most of the coking coal produced in India is washed to bring it up to the levels required by the iron and steel industry. However, non-coking coal is not being washed as yet. The debate on the economics of non-coking coal washeries has been going on for over a decade now with very little action resulting from it. The washing of non-coking coal would reduce the ash content of coal being supplied to the final consumers, reduce the transportation requirements and in addition produce rejects that could be utilized in fluidized bed boilers for generating electricity. Thus, a choice can be made between the use of unwashed non-coking coal and washed non-coking coal with significant differences in their environmental impact.

3.3 Choices in Energy Use

On the demand side, major "polluting" end-use activities would include industrial process heating, transportation and cooking.

The fuels commonly used for industrial process heat include coal and fuel oil. Significant potential exists for increasing the efficiency of providing process heat in India both by replacing existing inefficient old boilers with new more efficient domestically produced boilers as well as through importing new technologies. It is estimated that existing boilers being used in the country have an average efficiency of 45-50% whereas new boilers would have efficiencies in the range of 65-70%. It has also been estimated that a significant potential exists for combined heat and power generation which would increase substantially the overall system energy efficiency. Substituting coal and fuel oil with natural gas is also a viable option that would need to be looked at in greater depth.

Studies on energy consumption in the industrial sector have revealed potential for electrical energy conservation in the range of 25 to 30%. Most of the measures suggested for such improvements have pay back periods of less than 2 to 3 years. As industry accounts for nearly 60% of total electricity consumption in the country, improvements of this magnitude would have very significant benefits in terms of increased availability of electricity for alternative uses as well as reduced capacity expansion requirements which could have several beneficial environmental impacts.

Rail transportation acts as a major bottleneck as far as commodity movement is concerned which has lead to an increase in dependence on road transport modes for freight movement purposes. An expansion in the capacity of railways, electrification of routes wherever feasible, reduced turn around times etc. could have significant benefits in terms of reduced time required, lower costs, higher energy efficiencies, etc.

With respect to passenger transportation it is seen that by and large the railways are relied upon for long distance travel but for short distance travel there is an increasing use of private means of transport as against various public modes of transportation. This increase has largely been in the use of two-wheelers which are increasingly used by a large section of the population in the lower and middle income strata of urban society where they had earlier used public transport. Surface transportation has become a major source of air pollution in the four metropolitan cities of India (Delhi, Bombay, Calcutta and Madras). In our process of transportation planning, there is a need to consider environmental impacts.

Several options are available for higher efficiency in meeting the cooking energy requirements as well as quality of energy used by our growing population. One of the options that is being implemented in the rural areas of India is that option of biogas - natural gas that is being generated through anaerobic fermentation of animal dung and crop waste. The advantage of this technology lies in the fact that while providing a clean, efficient and convenient form of cooking energy, it also makes available all the nutrient contents of biomass forms for recycling back to the soil. The Govt of India has also initiated a programme on the dissemination of the improved chulhas which have efficiencies in the range of 20%. Other options that are available in meeting the cooking energy requirements include the use of solar cookers. Although it is estimated that a solar cooker could at best provide the equivalent of 2-3 cylinders of LPG per annum, this in itself could be a fairly significant contribution - both in terms of availability of cooking energy as well as reducing environmental pollution. Providing better designs for kitchens with proper ventilation facilities will go a long way towards improving the lot of the rural poor.

In addition to improved kitchen designs in the rural areas, improved building designs in urban areas could also play a major role in reducing the dependence on polluting forms of energy. Such designs would be of particular relevance for the end-use requirements of lighting and cooling/ventilation. Energy conservation in the domestic sector can be attained through a variety of measures that would include time-of-day tariffs for electricity, differential time zones, stringent standards for domestic appliances, providing the right price signals, etc.

Analysis of Energy Strategies Using the TEESE Model

Some of the choices that are discussed above were analyzed using the TERI Energy Simulation and Evaluation Model (TEESE). The TERI Energy Economy Simulation and Evaluation (TEESE) model is a macro level energy economy model that allows us to capture the structure of the economy as well as the requirements of energy for specific end-uses. The following cases were developed using the TEESE model.

Case 1 gives energy demand projections and emission levels for the year 1999-00 without major interventions in new technologies or efficiency increases.

Case 2 gives the results taking into account pollution abatement equipment.

Case 3 analyses the impact of efficiency improvements in domestic devices using electricity.

Case 4 analyses the impact of efficiency improvement in the industrial sector.

Case 5 assesses the impact of a lower rate of urbanization - 28% in 1999-00 against the base level of 33%.

Case 6 assesses the impact of higher availability of firewood on the system.

Case 1 - Energy Demand Projections for the Year 1999-2000: The TEESE model was run for the year 1999-2000 assuming a rate of growth of the economy of 5% per annum and a population of 972 million. The results from this case as well as the other five cases are summarized in Table 3.1 below. Total peak load on the system at 87,500 MW for the year 2000 is significantly lower than estimated by the 13th Electric Power Survey. Total electricity demand works out to 490 TWh, 10% of which is met through captive power generation sources.

Table 3.1 : Results from TEESE Model

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Peak load (MW)	87552	93277	85847	80537	85746	87542
Total electricity demand (TWh)	490.76	522.85	481.21	451.44	480.64	490.71
Coal non-coking (MT)	367	367	367	345	367	367
Washed coal (for power generation)	-	247.6	207.6	-	-	-
Unwashed coal	-	119.4	159.4	-	-	-
Imports	51.5	-	-	-	44.0	51.45
Gas (BCM)	17	17	17	17	17	17
For power generation	7.97	11.11	11.11	7.6	7.87	7.97
Oil (MT)	81.82	89.62	80.54	79.24	80.3	69.65
Import of HSD	9.44	6.57	6.64	7.22	8.38	8.96
Import of FO	0.11	15.8	7.00	-	-	-

The demand for primary forms of energy for Case 1 are summarized below.

Energy Source	Total Demand in mtoe	% of total
Coal	186.74	61.8
Oil	81.82	27.0
Natural gas	14.11	4.7
Hydro	14.47	4.8
Nuclear	5.27	1.74

Commercial energy forms for the year 1999-2000 account for 82% of total energy consumption with biomass sources accounting for the balance. Fossil fuel consumption in per capita terms is as follows:

(Units: Kgoe)

Source	1999-2000	1987 (Actual)
Oil	84	61
Natural gas	14.5	11
Coal	192	167

Thus, it is seen that fossil fuel consumption has increased significantly from 1987 levels. If no pollution abatement measures are adopted, SO_2 emissions would be in the range of 4.4 MT per year and NO_x, 2.5 MT per year.

Case 2 - This case presents the results allowing for pollution abatement equipment costs for some sectors of the economy (Appendix 1). It is seen that the non-coking coal washeries option is economical largely due to the reduced transportation requirements and for meeting electricity requirements through fluidised bed boilers. Thus nearly 67% of the non-coking coal produced domestically is washed and used for power generation purposes. The use of washed coal for process heat purposes is not economically viable. Thermal power plants located at various distances - from the pithead to over 1000 km - are all using non-coking coal. The rejects that are produced from the non-coking coal washeries are also being used for power generation purposes through fluidised bed boilers. As a result of these changes total electricity demand increases to 523 TWh and peak load to 93,200 MW, because electricity would be a cheaper option than other energy forms for certain end uses.

Freight transportation requirements reduce from approximately 775 BTkms (billion tonne-kilometres) to 684 BTkms - a reduction of about 12%. As a result of this, demand for diesel based road transportation goes down significantly and diesel import requirements are reduced from a level of 9.44 MT to 6.57 MT.

A larger amount of coal is now being diverted to the power sector as a result of which industrial process heat requirements are being increasingly met through the use of fuel oil. Thus fuel oil imports increased from an insignificant level of 0.11 MT to 15.8 MT whereas the petroleum product consumption goes up from approximately 82 MT to nearly 90 MT. Total energy system costs increase from Rs 80542 crores to Rs 87470 crores (an increase of 8.6%). However, the level of emissions level are reduced significantly as brought out in the section on Conclusions and Recommendations.

Case 3 - Case 3 presents the results of efficiency improvements in electricity utilization in the domestic sector, (taken at 50% of those actually achieved in Japan). Thus, it was assumed that refrigerators would be 25% more energy efficient and television sets and air-conditioners approximately 17% more energy efficient. As a result of these assumptions, total electricity demand reduces to 482 TWh and peak load to 86,000 MW. While in the first case 51 MT of non-coking coal had to be imported, in this case imports of non-coking coal reduced to 32 MT.

Case 4 - The potential for reducing energy consumption in important industry groups has been estimated at 30-40% thermal and 10.25% electrical. By taking these improvements into account, industrial demand for non-coking coal declined from a level of 196.0 MT to 136.6 MT reducing non-coking coal imports to zero. Electricity demand also declined from 264.5 TWh to 234.3 TWh. As a result, total coal based capacity declined from 49000 MW to approximately 42000 MW and coal demand for power generation declined from 240 MT to 208 MT. Demand for diesel for transportation declined due to the lower coal movement, reducing imports from a level of 12.4 MT to 10.2 MT. SO_2 emissions reduce by about 20% and NO_x emissions by 15% whereas particulate emissions reduce by 8%.

Case 5 - In this case, we have assumed that total urban population in the year 1999-2000 would be about 28% which is lower than the value projected on the basis of current trends. The main impact of this assumption is on the demand for household energy which reduces marginally. However, total household electricity demand reduces from a level of 82.7 TWh to 75.5 TWh - a reduction of almost 9%. This reflects itself in lower thermal generating capacity and hence a lower demand for coal for power generation at 230.7 MT - a reduction of 9 MT. Total petroleum product consumption also declines by about 1 MT - again largely due to a reduction in coal movement. SO_2 emissions reduce marginally by about 2%, NO_x by 3.3% and particulates negligibly.

Case 6 - In this case, we have assumed a higher availability of firewood at 150 MT against a base case level of 100 MT. As expected, the major impact of this was felt on the petroleum sector whose demand reduce to 71.6 MT. This reduction is almost solely due to reduced demand for kerosene by the household sector. As a result, kerosene imports reduce significantly from 11.8 MT to 1.3 MT implying major savings in foreign exchange. However, the environmental pollutant emissions as a result of the higher firewood consumption increase significantly. CO emissions increase by about 60% whereas suspended particulate matter increases by about 31%.

4. Conclusions and Recommendations

The growing degradation of India's natural resources and the demands of a growing economy have necessitated the formulation of a national conservation strategy to achieve sustainable development. In this context, a strategy for energy development would require an analysis of environmental impacts associated with different fuel cycles and the choices available to us.

In assessing the energy-environment interface, the following aspects of energy development have to be considered:

1) While energy supplies will not ¢dry up', nevertheless the existence of higher cost sources even in prevailing technologies may bias our decisions in favour of those energy sources that have relatively lower economic costs but high environmental costs.
2) Future environmental costs and benefits of energy choices are uncertain in many cases and, hence, future generations may be burdened by the decisions and the non-decisions of today.
3) From the point of view of the natural environment, "irreversibility" is associated more with the development of an area for purposes of resource extraction rather than the process of extraction itself. In this section, we summarize the elements that should constitute a national conservation strategy in respect of energy, based on the foregoing analysis and the deliberations of the workshop on energy and environment.

The results from running the TEESE model to evaluate aggregate environmental impacts and associated costs for the energy sector are summarized in Table 4.1.

Table 4.1: Base case energy system costs and change in emissions and costs with respect to base case (%)

Pollutant	Base case emissions Case 1 (million tonnes/yr)	2	3	4	5	6
SO2 (MT)	3.4	-52.6	-47.2	-22.9	-4.8	-2.5
CO (MT)	2.9	-5.1	-5.1	-2.4	-1.0	58.2
NOx (MT)	2.1	-56.0	-52.8	-17.6	-5.6	-2.8
SPM (MT)	0.5	-30.3	-28.6	-8.9	-1.8	30.2
Total cost (Rs crores)	80542	8.6	1.0	-11.36	-3.3	-2.7

This analysis is very useful and provides a powerful basis for articulation of long range strategies dealing with energy environment choices in the future.

The results of Case 2 indicate a substantial reduction in emission levels from energy activities as a result of mitigation measures that have been discussed earlier. The important observation from these results is a reduction as high as 56% of NO_x emissions, 52.6% of SO_2 emissions and over 30% of solid particulate matter from levels that would accrue if a business-as-usual approach was followed. These results are most persuasive in attesting the merits of such a strategy. Significantly, an increase in energy system costs of only 8.6% would bring about these major improvements.

Case 3 deals with efficiency improvements in the domestic sector which are, by any standard, conservative in terms of feasibility. In this case also there is an almost equal reduction in emission levels as shown in the summary Table of results. This improvement is even more attractive in economic terms since an increase of over 1% in energy costs is all that is required to bring about these major improvements. It must be emphasized, however, that the assumption behind the improvement of efficiency and reduction in energy intensity of domestic appliances is that these would not require any net additional outlays. These improvements would be economically viable and would therefore be driven by consumer choices. This presupposes that energy prices to the consumer would be rational and would reflect the total cost of power supply without subsidies which have a tendency to distort consumer preferences.

The case of industrial energy conservation brought out by Case 4 clearly establishes the viability of industrial energy efficiency improvements, because not only does conservation result in attendant environmental benefits, but total energy system costs actually come down by over 11%. It is, therefore, essential that energy conservation in the industrial sector be promoted at the national level as an important element of energy policy. In fact, several exercises in the past including the report of the Inter-Ministerial Working Group on Energy Conservation (1983) clearly brought out that the payback period from energy conservation investments in industry are such that up to 25 to 30% savings could be achieved without any investment at all, purely through improved housekeeping measures.

Case 5 assumes a lower rate of urbanization which also results in some marginal benefits in terms of environmental emissions but more notably brings down energy costs by 3.3%. The results brought out by Case 6 are mixed, indicating increased overall pollution in the form of higher carbon dioxide emissions are also of solid particulate matter. However, increased firewood costs lead to lower energy costs for the country, but this scenario indicates that perhaps while efficiency improvements in firewood consumption would be most desirable, a reduction in firewood used in the economy would be a desirable strategy, since this would reduce adverse environmental impacts. Consequently, a long term strategy for replacement of fuelwood by other forms of energy in cooking would be a preferred option.

Our analysis using the TEESE model provides a quantitative base for certain components of a conservation strategy which must guide future investments and options in the energy sector. It is clear that environmental protection measures for the energy sector would not be expensive in the time horizon of the analysis carried out. But if they are neglected, future costs of mitigation may increase substantially. Secondly, energy conservation through the introduction of improved efficiency in domestic appliances as well as energy saving equipment in the industrial sector would have highly favourable results which are in any case economically viable. The benefits of lower rates of urbanization are also clearly established, and the national conservation strategy must clearly emphasize this from the energy viewpoint through the adoption of a firm policy including incentives and disincentives for regulation of urbanization.

Reduction of firewood use in cooking is another measure for which a clear strategy for substitution by other and more favourable commercial fuels is desired.

The other presentations at the workshop have dealt with the environmental impacts of different energy supplying sectors and energy use sectors. Some of the points that have emerged are as follows:

1) In the case of coal mining it is felt that the potential areas for future coal mining fall in environmentally sensitive watershed areas and hence, it is necessary to distinguish between environmentally sensitive tracks where mining may not be desirable. Even though it is now necessary to develop an environmental management plan, the methodology of developing such a plan and implementing it is still evolving. This is one aspect where a major multidisciplinary effort in institution building and training is required.

2) In the development of the hydrocarbon industry the choice of refining capabilities seems to lie more on economic decisions rather than on environmental factors. In the case of off-shore oil development, contingency plans for accident management require greater attention. Vulnerability of different ecosystems towards these activities has to be incorporated in the decision making process. The flaring of natural gas should be reduced.

3) It has been identified that the air pollution generated due to thermal power can be managed in all cases except CO_2. This, in future, may lead to reduction in the use of coal as a fuel for

power generation. In addition, environmental impacts associated with the management of solid waste from thermal power plants is to be a major concern.

4) In the case of hydro-power generation, the large land requirements and the long term hydro-geological impacts as well as the overall impacts on the ecosystem call for a more moderate development of hydropower. It has also been pointed out that the costs of development of catchments should not be totally added to the hydro-power costs as this would unjustifiably make a project non-viable.

5) In the case of nuclear power the concerns today are related to poor performance, cost and time overruns. The impacts associated with an accident have made this option an unfavourable one.

6) There is an urgent need for conserving power considering the large trade offs that can be achieved in terms of savings in investments and conservation of the natural environment.

7) In the transportation sector the two-wheelers and three-wheelers are observed to be the major sources of pollution. It was felt that local devices to control pollution can be developed and used.

8) In the household sector the need for R & D to develop clean cooking devices based on biomass fuels has been identified as it is assumed that biomass is going to be our major cooking fuel.

9) In the context of problems associated with transportation and household energy use the issue of planning for urban settlements

has been raised and the need to plan them in an environmentally sustainable manner emphasized.

10) In view of the deteriorating biomass situation in several parts of the country it is felt that the question of common property resource management needs to be addressed explicitly so that conflicts in land use can be resolved to promote greater production of biomass for meeting the needs of the population.

11) To carry out a more detailed exercise to choose energy sector options using TEESE model a comprehensive energy-environment data needs to be built. This will include data on energy parameters, emission factors, inventory of susceptible eco-systems, vulnerability indices etc.

The workshop has identified several measures that need to be taken to ensure a sustainable development orientation in development policies. These include:

1) The urgent need to establish a system of accounting which quantifies damage to the environment as a result of specific economic activities. In essence, indicators of growth such as GDP and GNP would then be replaced by a measure which clearly identifies the negative effects of growth such as those which produce environmental degradation.

2) Environmental impacts need be included and quantified in project appraisal exercises. Each project document should ideally carry a full quantification of costs and benefits for the environment vis-a-vis the project appraised.

3) In order to ensure that environmental considerations are included fully in project appraisal and project identification exercises, it is important to train staff who are engaged in the identification and design of energy projects on environmental costs and benefits. Hence, engineers in the state electricity boards, those responsible for coal mining operations and oil exploration and refining must be well versed in the techniques of environmental impact assessment and appraisal. This can be achieved through a programme of on-the-job training, apart from greater intensification of courses on the environment in universities and engineering institutions.

4) The overall impacts of economic restructuring with respect to environmental effects need to be incorporated in the planning process. For instance, the environmental benefits of public transport systems versus the proliferation of private vehicles may justify a much more rapid and larger shift to public transport in several parts of the country. Similarly in the choice of industrial technology and products, a shift in the structure of industry may be desirable. An optimal choice of economic structure and industrial impacts can only be evaluated if such an appraisal is integrated within the planning process.

5) Resource use decisions are likely to promote sustainable development only if they involve local communities who are often the main losers when the stock of natural resources is destroyed or depleted. This applies as much to deforestation as to soil erosion and air pollution. Not only must the choice of standard setting be left to local communities, but decisions involving the

actual use of natural resources must be implemented only with the full participation and approval of these communities. New institutional and organizational mechanisms for ensuring this would be essential to attain this objective.

6) Since larger use of energy implies proportionately large environmental impacts, awareness of the importance of energy efficiency and emphasis on energy conservation is essential to reduce damage to the environment. The adoption of more efficient energy technologies calls for a reorientation of our R&D establishments away from supply-related problems to examining specific end-uses and devices.

7) Greater emphasis on renewable energy forms and technologies would accrue from consideration of environmental impacts, which are unsustainably high in the case of large energy projects using conventional fuels. Even in the case of hydro-electric projects, the environmental impacts can be serious and large in magnitude. Much greater research and development effort is, therefore, necessary for promoting the development and use of renewable energy technologies. Their importance lies not only in the fact that they are renewable but also in their characteristics that make these resources eminently suitable for our social organization and provide an alternative to the large-scale centralized energy systems of our current energy situation.

8) The focus on energy planning should shift towards decentralized decision making, since this would ensure capabilities and decisions favouring smaller energy projects

which by themselves would reduce the overall impact on the environment.

The process of sustainable development would require that all the considerations and approaches mentioned above be integrated into the methodology of development planning.

APPENDIX 1

ENVIRONMENTAL COSTS INCLUDED IN THE MODEL

The costs of pollution abatement included in the analysis using TEESE model are summarized below.

In the case of the domestic sector, a major activity that has been taken is the cooking energy requirement in rural households. The only cost that has been incorporated is the replacement cost of traditional stoves with improved stoves with a chimney. This would merely transfer the pollutants from inside the house to outside the house.

In the case of the industrial sector, emissions from industrial coal boilers have been taken into account both before and after the installation of cyclonic seperators. The cost of a cyclonic seperator for a 5 tonne boiler was taken at Rs 50,000 and for a 10 tonne boiler at Rs 75,000. In the case of fluidized bed boilers, costs including those of bag filters have been taken in the range 2-3 lakhs of rupees.

For coal mining, environmental costs have been estimated in the range of 10-15 rupees per tonne. For non-coking coal washeries, following parameters have been taken.

Cost of Washery	278.4×10^{6} Rs/4.5 MTPA
Annual washery cost	38.4% of the capital cost
Ash contents of washed coal	34%
Yield of washed coal	84%

The rejects produced in the non-coking coal washery are assumed to have calorific value at 1700 Kcal/kg. These could be used in fluidised bed boilers for power generation purposes.

Salient parameter of which are as follows.

Capacity	30 MW
Capital cost	Rs 604.5×10^6
Operating & maintenance cost	2.5% of capital cost
Interest during construction	22.5% of capital cost
Boiler efficiency	77%
Oil consumption	10 ml/kWh
Auxilliary consumption	9.5%
Reject-handling cost	Rs 20/tonne
Overall plant heat rate	3417 kcal/kWh

In the case of thermal power plants, the cost of electrostatic precipitator (ESP) for a 210 MW plant using 40% ash coal was taken at Rs 30 million. If a plant was to use to washed coal with an ash content of 34%, the cost of ESP declines to Rs 1.35 million. Costs of flue gas desulfurisation (FGD), nitrogen oxide control and solid waste control have been taken from Mathur and Sridharan (papers presented at the workshop).

In the case of hydropower plants, some sample data was collected on specific projects that took into account population displaced, agricultural area affected and forest area affected. Costs were assigned to each of these by looking at the opportunity costs of the land submerged as well as the compensation required to be given to the displaced persons.

While technologies had been identified for controlling vehicular pollution these have not been incorporated as yet in the model as we have not been able to obtain the costs of these.

List of Papers Presented at the Workshop

1. Assessment of Environmental Impacts using TEESE Model -(Gupta, Dr R.K. Pachauri, Ms Leena Srivastava
2. Environmental Issues in Coal Mining and Transportation - Mr P.V. Sridharan
3. Environmental Concerns Associated with Hydrocarbon Development - Dr Maria Ligia Noronha
4. Environmental Concerns of Oil Refining - Dr Kapil Thukral
5. Environmental Impacts of Thermal Power Generation - Dr Ajay Mathur
6. Environmental Impacts of Hydro-Power Generation with special reference to Koyna Hydroelectric Project - Dr S.K. Guha
7. Environmental Impacts of Nuclear Power Generation - Dr T. Subbaratnam
8. Energy Strategies and the Greenhouse Effect - Dr R.K. Pachauri and Dr. Vivek Suri.
9. Impact of Surface Transport on Air Environment of Major Metropolitan Cities in India - Prof. H.B. Mathur
10. Environmental Impacts of Energy Use for Cooking - Dr Veena Joshi
11. Indian Himalayas: Environmental Issues and Conservation Stragtegy - Dr N.P. Melkania
12. Management of Biomass Resources - Mr A.N. Chaturvedi
13. Energy Conservation in Industry and Environmental Benefits - Mr G. Sambasivan
14. Environmental and Occupational Health Monitoring in ONGC - Dr S.M. Sharma